Balance and Escapement Traits

Mark Lee

Preface

Gathering the stand-alone essays into a collection has prompted the revision of several related features. The first task was to expand these compositional guidelines uniformly to all of the Escapement Trait essays:

> *... the desired result of using a hierarchical identification system is to systematically illustrate the traits of an escapement's overall character. Its use is not intended to define the primacy of one trait over another. Due consideration must be given to the variations exhibited by a single trait in both an escapement's static and dynamic conditions. The static descriptions of these traits, however, can be difficult to associate with the dynamic nature of the mechanisms and consequently, when feasible, hyperlinks to dynamic images have been provided.*

Two new essays have been added to the collection and these guidelines have been observed as closely as possible. These essays offer some fundamental balance and escapement information without requiring a reader to "sift" through an entire research library. The writing of a definitive opus is left to others.

The new Reference section, unlike a print bibliography, lists only immediately accessible electronic material. A word of caution, however, is necessary. All of the materials are freely available to browse, read, or copy for personal use. Copying for the purposes of re-publication or distribution is restricted. Only the Project Gutenberg electronic texts are in the U. S. public domain. The rest (texts and web sites) are protected by the copyright restrictions of their respective owners. *Please comply with these copyright restrictions.*

Certainly not of the least importance is the acknowledgement of some of the individuals who have "sharpened" my appreciation for timekeeping mechanisms. The previous stand-alone format of the essays really precluded such mention and now this shortcoming has been (partially) addressed. Additionally, I would add my thanks to "a cast of thousands" for the assistance which has been extended to me.

- Mark Lee

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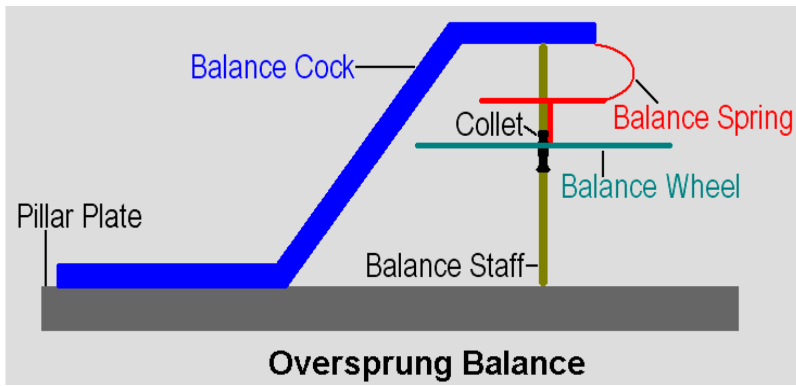
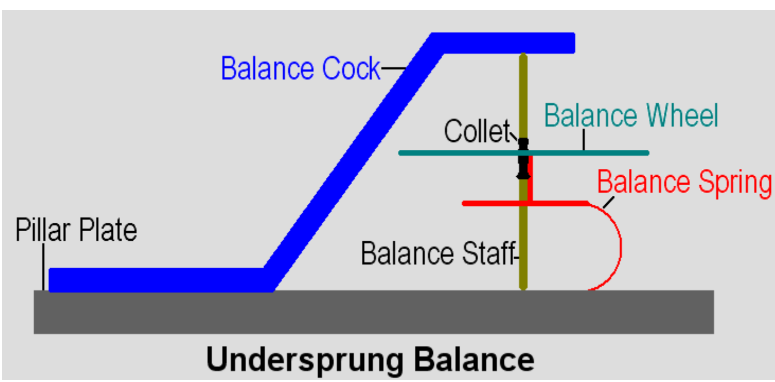
Balance Traits:
Oversprung and Undersprung Balance Wheels

Important note: *The drawings below are not made to scale. For the sake of clarity they are greatly simplified.*

The more common installation of a balance spring (hairspring) is technically referred to as an Oversprung Balance. The balance spring is installed above the balance wheel. Its inner end is anchored to a "collet" which is fixed to the balance staff. Its outer end is attached to the balance cock with a stud. The mass of the balance spring is located above the balance wheel.



A less frequent installation method is technically named an Undersprung Balance. Unlike the Oversprung Balance, the balance spring is mounted beneath the balance wheel. The inner end is secured to the balance staff's "collet" while the spring's outer end is pinned to a permanently fixed stud mounted to the pillar plate. The mass of the balance spring is located under the balance wheel.



Balance Traits:
Quick Train

The speed of a watch movement is expressed in vibrations per hour (abbreviated VPH or V/H). These vibrations are the turnings of the balance wheel. The movement of a point on the balance wheel (Z in diagram 1) from one extreme of its arc of rotation (A) to the other extreme of the arc (B) is one vibration; the movement back in the opposite direction is another vibration.

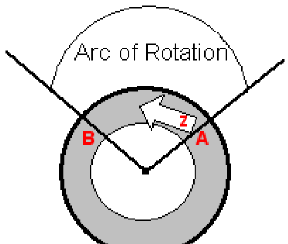
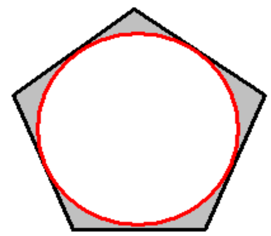


Diagram 1

The operating speed of a timepiece reflects its potential accuracy. The more quickly a timepiece vibrates, the closer it approximates the sidereal time of the Earth's rotation. Graphically, the duration of a sidereal hour can be represented as a circle. The total number of vibrations which are equal to a sidereal hour are represented as a polygon enclosing the circle (diagram 2). Each vibration represents the length of a side of the polygon. The polygon approximates the outline of the circle as closely as possible within the confines of a timepiece's designed arc length and impulse delivery speed. Reducing the length of the arc and increasing the speed at which an impulse is delivered to the timepiece's escape mechanism, becoming a "Quick Train", reduces the variance between a timepiece and the sidereal time it mimics (diagram 3).


Digram 2

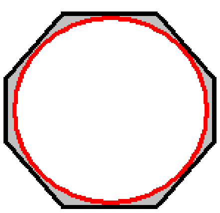
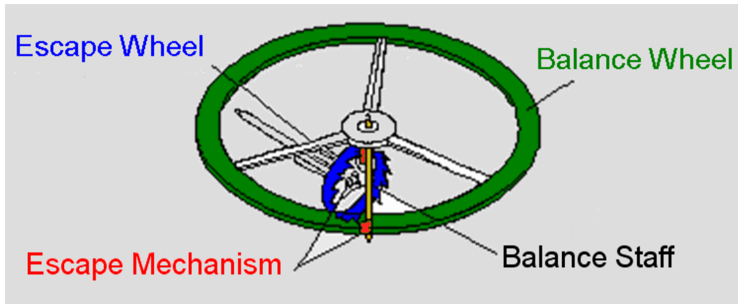


Diagram 3

The term "Quick Train" originally referred to the increase of vibratory speed from 14,400 vph to 18,000 vph. The term is now relative as operating speeds higher than 18,000 vph have been achieved. Speeds of 21,600 vph and 28,800 vph are not unusual in high quality mechanical watch movements.

Escapement Traits: Friction Rest and Detached

An escapement is that device which allows a mainspring's power to "escape" its confinement and transmit an impulse of energy. Watch escapements fall into one of two broad categories. The illustrated Verge escapement is categorized as having a Friction Rest trait. In a Friction Rest escapement, during the rotation of the balance wheel, the balance staff always remains in contact with the escape wheel itself, or an element of the escape mechanism. In short, the balance staff is not free turning.



Another escapement type which shares this trait is the Cylinder escapement. The Detached escapement, however, is only in contact with the balance staff at the moment of impulse and allows the balance staff to be free turning. Both the English Lever and the more familiar Swiss Lever are escapements which represent this trait.

Escapement Traits:
Single and Double Beat

The vibrations of a watch mechanism are the turnings of its Balance Wheel. The movement of a point on the balance wheel (Z in Diagram 1) from one extreme of its arc of rotation (A) to the other extreme of the arc (B) is one vibration (forward). The movement back in the opposite direction is a second (or return) vibration (Diagram 2). These two vibrations combined in a single cycle comprise an oscillation.

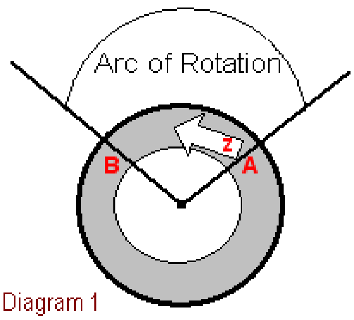


Diagram 1

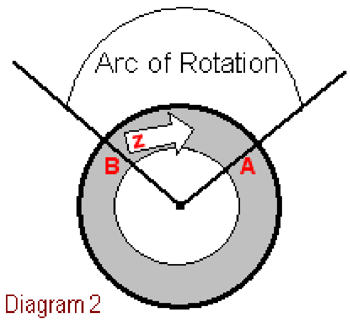


Diagram 2

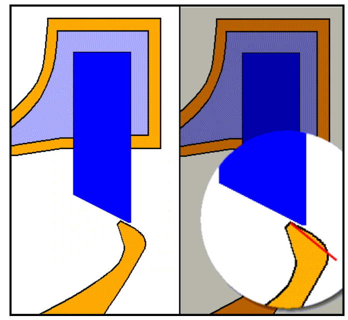
In a Single Beat Escapement, an oscillation describes the release of only a single energy impulse. During the return vibration (B to A), the Single Beat escape mechanism is designed to maintain a lock on the Escape Wheel thus preventing it from delivering a second impulse. *The impulse release is confined only to the forward A to B vibration.* Both the Détant (static)(dynamic) and the Duplex (static) (dynamic) mechanisms are Single Beat Escapements.

An oscillation which encompasses the release of two energy impulses, one per vibration, is controlled by a Double Beat escape mechanism. The Cylinder (static)(dynamic), the English Lever (static) (dynamic) and the Swiss Lever (static) (dynamic) are all examples are all examples of the Double Beat Escapement. The Debaufre Escapement is beguiling in appearance; nonetheless, it is a Double Beat escape mechanism. Its two escape wheels are fixed in a staggered position on a common arbor and uniformly turn as one. Consequently, two energy impulses per oscillation are released due to the staggered impact of the teeth. The escapement s basic design is also known by the additional names "Chaff cutter", "Chopper", "Clubfoot , "Gautier" and "Ormskirk".

Escapement Traits:
Lift and Draw

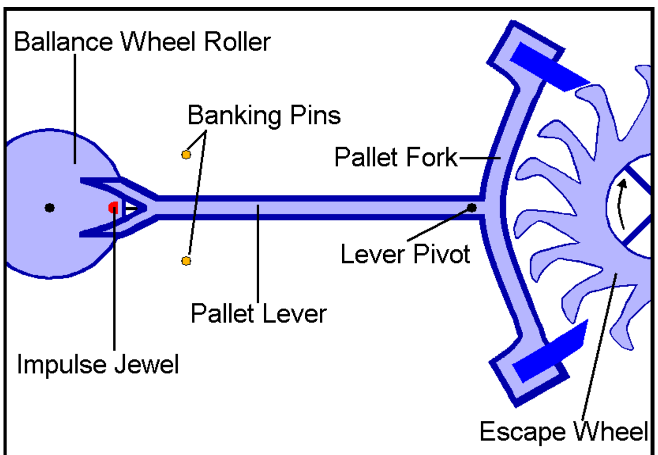
Important note: The images below have not been drawn to scale and have been greatly simplified. Terms in red correspond to labels in the second image.

"Lift" and "Draw" are two of the more ambiguous traits associated with watch escapements. In general, they are best described as static features which impact the dynamic action of the escapement.



"Lift" is a trait of both friction rest and detached escapements. It functions in two ways. The first is to shape the impacting pallet or tooth face to optimize the transfer of the energy impulse; and the second is to reduce the area of impact to minimize friction. A "divided lift" mechanism would have both shaped pallets and escape wheel teeth. Whichever element (pallets or teeth) is shaped is the "lift" element.

"Draw" is a feature of straight lever escapements made after the turn of the 19th century (early lever (and rack lever) escapements are "deadbeat" systems). Operating power is supplied by the mainspring through the drive train ending at the *escape wheel*. The *pallet lever*, acting in conjunction with the *balance wheel roller*, regulates the power's release. Swinging on its *pivot*, the pallet lever reciprocates from side-to-side. When the mainspring's power is conveyed to one of the pallets, it is transmitted by the reciprocating pallet lever to the *impulse jewel*. The impulse jewel, located on the balance wheel roller, is a fixed part of the balance assembly. Receiving the power impulse, the balance wheel is propelled through its arc of rotation.



Straight lever escapement.

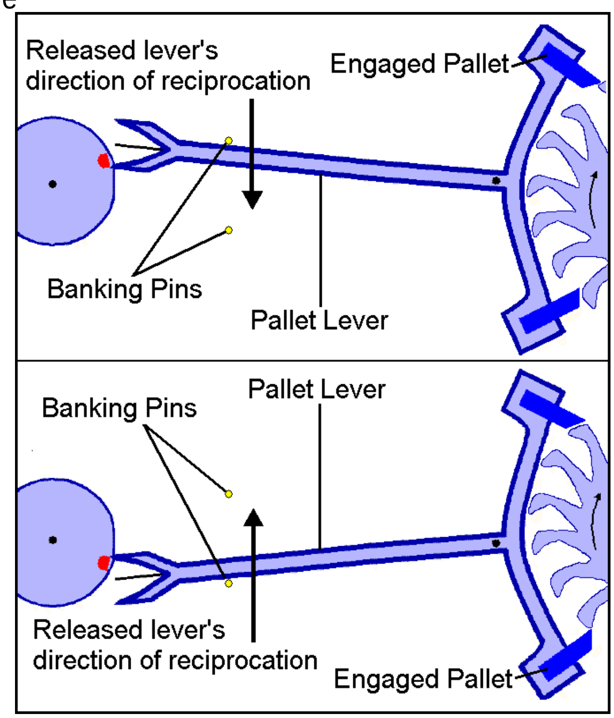
During the dynamic action of the mechanism, the pallet lever is "drawn" snuggly against either of the *banking pins* and firmly held in place until released by the reciprocating action action of the pallet lever. Also, the individual pallets draw closer to the center of the escape wheel. In design layout, closely locating the *pallet fork* to the escape wheel allows for a deeper meshing of the pallet fork's pallets with the escape wheel's teeth. The intension is to provide a more secure interaction between the two elements. The escapement's overall detachment is maintained, however, by the curved edges of the escape wheel's teeth which allow the pallets to pass without contact.

Escapement Traits:
Recoil and Deadbeat

Important note: The images below have not been drawn to scale and have been greatly simplified. Terms in red correspond to labels in the image.

"Recoil" and "deadbeat" are terms which express general dynamic characteristics of an escapement. They can be used to explain the action of either single or double beat systems as well as either friction rest or detached escapements.

When discussing double-beat escapements, the term "recoil" is used to indicate the reaction of a releasing pallet. In early Verge escapements, the recoil can be strong enough that the drive train is pushed backwards producing a visible 'stagger' in the forward progression of the hands. Due to its constant contact with the balance system, the single-beat Duplex escapement also generates generates "recoil". The 'stagger' is produced when an outer escape wheel tooth slides into and out of the balance staff's bypass slot.



Never-the-less, by design "recoil" can be controlled to be beneficial to the function of the escapement. When a double-beat straight lever escapement is in motion, the *pallet lever* is held slightly tighter against a *banking pin* than the *engaged pallet* is held against an escape wheel tooth. As a result, the banking pin to pallet lever contact point becomes the location of the "recoil". As the opposite pallet is engaged, the pallet lever's contact with the banking pin is relaxed. The *released lever's direction of reciprocation* is the same direction in which the recoiling force moves. The "recoil" energy is incorporated into the reciprocating pallet lever's motion and is not transmitted back against the drive train.

"Deadbeat" is the opposite of "recoil". In "deadbeat" escapements there is no push-back. Both the Cylinder and the Rack Lever designs are double-beat escapements which illustrate this trait. The Détant design, a single-beat escapement, is detached. A Détant escapement, not being in constant contact with the balance system, does not generate any "recoil" energy and consequently is considered a "deadbeat" escapement.

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Mr. David Todd, the Associate Curator Emeritus of the Timekeeping Collection of the Smithsonian Institution.

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